95 Egypt. J. Chem. Vol. 68, No.2, pp. 573 -581 (2025)

Egyptian Journal of Chemistry

http://ejchem.journals.ekb.eg/

Enhancement of Agriculture Drainage Water Quality Using Bio-Reactor

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Abstract
Constructed wetlands are considered a cost-effective and sustainable alternative to traditional methods for water treatment. They act as bioreactors in water treatment. This research investigates a non-conventional treatment approach using constructed wetland to reduce the concentration of pollutants downstream the agriculture drains to achieve the allowable law limits of Egyptian law (Law 48 for 1982) for reuse purposes. Field samples have been collected to assess the water quality of El Khadrawia drain and the point of connection with El Atef drain. For the point of connection with El Atef drain, the field samples have been collected during the summer (the worst operational period) at two locations: before and after the connection point. For El Khadrawia drain, seasonal field samples have been collected for analysis in a location just before joining El Atef drain by 1.5km. The treatment approach is to construct a wetland pond using Lemna plants as media. Pilot is done with a quantity of water from the drain equal to 30 m^3/day for the pond. The density of lemna plant is 40 gm/m^3. The wetland pond dimensions are (10*7.5*1.0 m) with an untreated drain water depth of 40 cm and inlet and outlet pipes of 4 inches with slope 1:1. The pond is isolated with polyethylene sheets to avoid seepage. The results show that El Khadrawia drain water quality achieved the required limits to reuse drainage water for other purposes using the mentioned treatment approach, moreover this approach is effective environmentally, technically, and economically.

Keywords: Drainage water, Treatment approaches, Constructed Wetland pond, bioreactor

1. Introduction

Water scarcity is an increasing problem on every continent, with poorer communities most badly affected. To build resilience against climate change and to serve a growing population, an integrated and inclusive approach must be taken to managing this finite resource. [1]. One of these poor countries is Egypt which is suffering from water scarcity. So, it needs non-conventional water resources to overcome the increasing in water demand, especially the agriculture sector which needs about eighty five percent of the total water budget [2,3].

Water pollution is the contamination of water bodies (like oceans, seas, lakes, rivers, aquifers, and groundwater) usually caused due to human activities. Water pollution is any change in the physical, chemical, or biological properties of water that will have a detrimental consequence on the environment and living organisms. There are three types of contamination. First, Physical contamination which means any change occurs to any physical properties of water such as temperature, color, odor, taste. Second, Biological contamination is the change in the microorganisms (bacteria, algae) that are present in the water. Third, Chemical contamination and means the changes occur for any chemical properties of water such as pH value, TSS, TDS, COD, alkalinity...etc. [4,5].

Plus, the water pollution problem, there is a major problem facing the agriculture water includes insufficient irrigation systems, groundwater scarcity, climate change, water and food shortages, the reusing of waste, and so many others. The outcome of agriculture is significantly influenced by the acceptance of various cognitive solutions. More food and agricultural crops are urgently needed to feed the world's increasing population, which considers for an appropriate supply of water. Water remains the most crucial element in agriculture and other human activities. The conventional approaches managing irrigation water are not up to standard with the growing demand.[6]

Many control approaches have been held recently worldwide to understand the cause of pollution, start monitoring plans for the sources of contamination, find out the contaminant's indicators, start an inspection plan, set up a legal framework and finally find out the best economic, technical, and environmental solution [7]. Also, many environmental approaches take place

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Receive Date: 17 March 2024, Revise Date: 21 July 2024, Accept Date: 03 August 2024
DOI 10.21608/ejchem.2024.277183.9470

to resolve the problem of any contaminants like complying the discharged water with the limits of the law, find out new limits and high precautionary controls for the discharge or extract a new equation for application on the dispersion of contaminants [8,9].

In non-conventional analysis of water quality and treatment for agriculture drainage for reuse practices, many factors are considered for optimization, such as costs, economics, technical impact, and environmental factors, including public health factors, energy requirements, treatment and reuse options, The ease of construction, operation, and control, and the ease of maintenance of the system [10]. In 2024 Dawen, G., Nabi, M.stated that There are several challenges in constructing wetlands that must be handled to modify their effectiveness and sustainability. The challenges such as the required land areas, to remove nutrients a complex treatment steps will be needed, finally maintenance costs are High [11]. In general, any treatment process should optimize at least one of the variables mentioned before. Furthermore, a system which could optimize more than one variable should be more acceptable [12]. Also, in 2023 Anil, A. et al studied the constructed wetlands effect to treat wastewater, especially in removing organic matter and suspended solids, Indian cities were chosen as case studies that integrate system and natural wetlands [13]. Also, in 2022 Waly. M, made review paper on constructed wetland and stated that using CW as a secondary or tertiary treatment technology, initial treatment should come first for optimal CW operation. The removal of several parameters, including TSS and BOD5, COD, NH4, and the possible risk of system clogging, during this preliminary treatment increased the efficiency of the system. Based on the review, more research is required in the field of CW to better utilize new substrates, such as industrial waste materials and agricultural byproducts, plant type, and the degree of preliminary treatment in the event of different contamination events under different conditions [14].

In 2022 Laura B. Mc. Calla studied the impact of using constructed wetland treatment system with a granulated activated carbon (GAC) filter installation to reduce agriculture pesticide concentrations and associated toxicity and the results show that the constructed wetland system coupled with GAC filtration reduce the concentrations of agricultural pesticide, nutrients, suspended particles, and aquatic toxicity associated with agricultural runoff [15].

This research tried to study the constructed wetland using Lemna plants to treat El-Khadrawia drain agricultural wastewater.

2. Research objective

A cost-efficient and eco-friendly solution was proposed to overcome the negative impact of direct disposal for agriculture drainage (El Khadrawia drain) on El-Atf Drain and to be reused for agriculture purposes.

3. Materials and methods

3.1 study location

El-Khadrawia drain is one of the most polluted drains in Egypt. It starts in the Menoufiya governorate passing centers including Brket El-Saba, Quesna, and ends in the Western Province center Zifta. The length of ElKhadrawia drain is about 35 km and has an average disposition of the drain at the downstream about 400,000 m^3/day. Figure (1) shows the location of El Khadrawia drain.

Figure (1) El Khadrawia drain location

3.2 Data collection

In order to make an assessment for the study area and determining the effect of El Khadrawia drain on El Atef drain, water samples have been collected for a location (A1) 1.5 km before and location (A2) 1.5 km after the intersection between the two drains. Three samples are recorded at the summer season (end of June, end of July & end of August) as it's considered the worst operation condition for both drains.

In addition to what has been mentioned, three seasonal field samples have been recorded for El Khadrawia drain during (spring, summer, autumn, winter) to monitor & evaluate the water quality parameters for the drain.

3.3 Pilot of the constructed wetland

As result of the water quality analysis of El Khadrawia drain, a non-conventional treatment approach has been proposed to treat it. A pilot had been constructed to check the possibilities of minimizing the pollutants load in the drain water to be within the allowable limits of Law 48 for 1982 for reuse purposes. The approach was constructing a wetland pond using lemna plant as a media. Pilot is done with quantity of water from drain equals 30 m^3/day for the pond. The density of lemna plant is 40-50 g/m^3. The wetland pond dimensions are (10*7.5*1.0m) with untreated drain water depth 40 cm and inlet and outlet pipes 4 inch with slope 1:1. The pond is isolated with polyethylene sheets to avoid seepage.

4. Results and Analysis

This part of the paper will illustrate the results and the discussion of the experimental work. First, for the assessment area which is at the connection between el Atef drain and El Khadrawia drain during Summer season. Second, for ElKhadrawia drain during the four seasons. Third, for the treatment approach proposed.

4.1 Experimental results

This part of the paper illustrates the experimental results for the assessment area which is at the connection between el Atef drain and El Khadrawia drain during summer season, and for El Khadrawia drain during the four seasons and for the treatment approach proposed.

4.1.1 El Atef drain, the assessment area

Field samples are taken through the summer season at the end of the three months (June, July & august) for El Atef drain. The samples are taken at a point 1.5 km just before and after the direct disposal of El Khadrawia drain in a rate of one sample per month. (A1) is the location of the sample in El Atef drain before the disposal of El Khadrawia drain, and (A2) is the location of the sample in El Atef drain after the disposal of El Khadrawia drain. Laboratory analysis is recorded. Tables (1) & (2) illustrate the water quality analysis for locations (A1) and(A2).

The assessment area, location (A1)

The results cover the measurements of water quality parameters for El Atef drain during the summer season as it's the worst operation conditions. The location of the samples (A1) are taken after the connection point with the El Khadrawia drain shown table 1.

It is noticed that the results show that the water quality parameters exceed the permissible limits according to law (48) for (1982) regarding (DO, BOD, TN, TP, COD, TDS, TSS). This is due to the direct disposal of several drains to El Atef Drain without any treatment approaches.

Table (1) shows the average water quality parameters at location (A1) in El Atef Drain

Parameter (mg/l)	R (average)	Law limits (48 for 1982)
Temp.*	38.6	Not more than 3 degrees of the recipient water body
PH value**	7.94	6:9
DO	3.78	Not less than 4
BOD	40.6	30
Ammonia	1.98	0.5
COD	109	50
TSS	32	50
TDS	1176	1000
T. P	3.21	3
T. N	17.86	15
LEAD	0.12	0.01
Cadmium	0.12	0.01
Chrome	0.12	0.05
Sulphates	0.86	--
E. coli***	1313	1000

*Degree
** N/A
***CFU/100 ml

The assessment area location (A2)

The results cover the measurements of water quality parameters for El Atef drain during the summer season as it's the worst operation conditions. The location of the samples (A2) are taken after the connection point with the El Khadrawia drain. Table (2) shows the average water quality parameters at location (A2) in El Atef Drain.

From table 2 the recorded results of El Atef drain after joining El Khadrawia drain, it is very clear that the water quality in El Atef drain is getting worse after Khadrawia drain joining the stream. As well as it isn't within the allowable limits for the governing law (48) for (1982). The presence of great variations DO, BOD, COD, TDS, TN & E. coli, as recorded in the above tables, causes severe negative environmental impacts on the water quality in the drain.

Table (2) Average water quality parameters in El Atef Drain at location (A2)

Parameter Mg/l	R (average)	Law limits (48 for 1982)
Temp.	39	Not more than 3 degrees of the recipient water body
PH value	7.94	6:9
DO	3.2	Not less than 4
BOD	52	Not more than 30
Ammonia	1.73	--
COD	142	Not more than 50
TSS	65	50
TDS	1905	Not more than 1000
T. P	3.24	3
T. N	18.46	15
LEAD	0.125	Not more than 0.01
Cadmium	0.13	Not more than 0.01
Chrome	0.14	Not more than 0.05
Sulphates	0.86	--
E. coli	1916	1000

*Degree
** N/A
***CFU/100 ml

4.1.2 EL Khadrawia drain.

Water samples are collected from the drain. Laboratory analysis is recorded for the water quality analysis during the four seasons.

The location of water samples of El Khadrawia Darin is at point (K). This point is just 0.5 km before the direct disposal of the drain to El Atef Drain. The following figure shows the location (k).

4.2 Proposed treatment approach: constructed wetland: leman plant pond

As a result of the assessment for El Khadrawia drain & El Atef drain, a proposed solution to treat El Khadrawia drain is mentioned here to enclose the water quality of the drain to be within the allowable law limits for reuse purposes.

The proposed solution was to construct a wetland. with Lemna plants. The area of the wetland is designed with an area of (10*7.5*1m) with depth (0.4 m). The pond is covered with polyethylene sheets to avoid seepage. The retention time is 7 days.

The treatment approach has been done through the summer season, during (June, July, August) as it's the worst operation period. The samples are recorded at the end of each month just after the wetland and before the disposal in El Atef Drain. Three samples are taken in a time frame of 3 months.

4.3 Discussion of results

This part of the paper will illustrate the experimental results discussion for the assessment area which is at the connection between el Atef drain and El Khadrawia drain during summer season, El Khadrawia drain during the four seasons and the proposed treatment approach**.**

4.3.1 Study area assessment: location A1&A2

The previous results show the water analysis for El Atef drain water sample. The values of the water quality analysis highlighted that many parameters aren't complying with the Law (48). The main parameters that are against the law were DO, BOD, COD, TN, TP, TSS, TDS, & E. COLI.

Chemical oxygen demand COD

Regarding COD parameter, the analysis shows that the value of COD in the samples exceeds the allowable law limit which is (50 mg/l). As shown in figure (2) the values of COD in both locations (A1&A2) of El Atef drain are represented and location A2 is more contaminated than location A1.

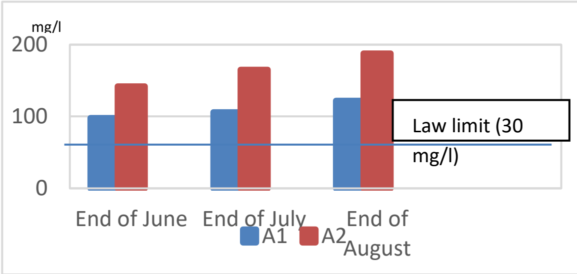

Figure (2) Values of COD for locations (A1&A2)

Biological oxygen demand BOD

In terms of the BOD parameter, the analysis reveals that the sample's BOD value exceeds the permissible limit in law (48) which is (30 mg/l). The BOD levels at both of El Atef drain locations (A1&A2) are displayed in Figure (3).

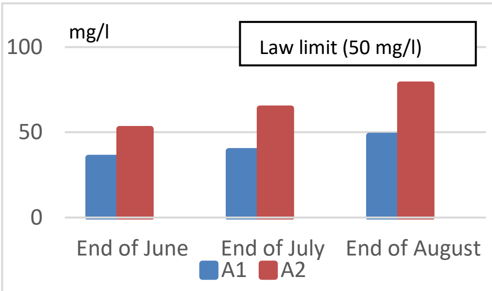

Figure (3) Values of BOD for locations (A1&A2)

Dissolved Oxygen DO

According to the analysis, the sample's DO value is below the allowable law (48) for (1982) in which is (not less than 5 mg/l). the levels of DO in both is shown in Figure (4).

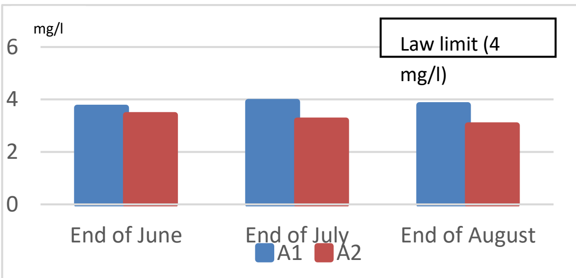

Figure (4) Values of DO for locations (A1&A2**)**

Total Dissolved solids (TDS)

With respect to the TDS parameter, the analysis indicates that the value of TDS in the sample exceeds the permissible limit in law (48) for (1982) which is (not more than 1000 ppm). The TDS values in both locations (A1&A2) of the El Atef drain appears in Figure (5).

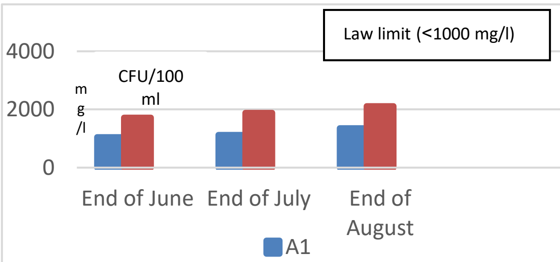

Figure (5) Values of TDS for locations (A1&A2)

Beside the previously indicated information, the analysis indicates that the ammonia parameter and E. coli readings don't correspond to the permissible values of law (48) for (1982).

As a general notice, it was obvious that for all studied parameters location A2 is more contaminant than location A1. That is reflecting the bad impact of El Khadrawia drain on El Atef drain. So, it becomes a must to assess to analysis its water quality conditions.

4.3.2. El Khadrawia Drain assessment.

Figure (6) shows the comparison of the parameters of (BOD, COD, DO, TSS, E-coli and TDS) throughout the four season with respect to law (48) for (1982) allowable limits for reuse practices.

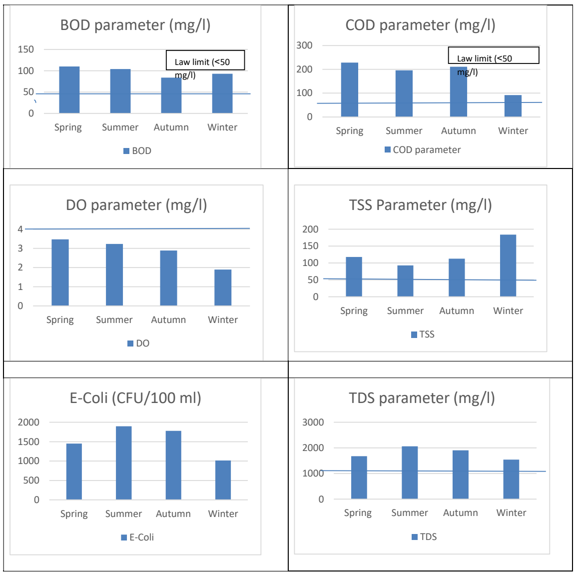

Figure (6) Average Values of DO, BOD, COD & TSS for location (K)

It was noticed that all the studied parameters are exceeding the allowable Law limits. Summer and Spring recorded the highest value in all parameters as the high temperature caused increase in the rate of evaporation that leads to increase in contaminants concentration.

4.3.3 Construction of wetland pond

The proposed treatment method was using a constructed wetland as a natural and eco-friendly treatment system. The main target of the proposed natural treatment method is to maintain the water quality of El Khadrawia drain to be within the allowable Law 48 for 1982 limits for reuse purposes.

During the summer, the effluent from the pond's water quality analysis was measured. The water quality parameters of the influent and effluent are listed in Table (3-a).and table (3-b)

Table (3-a) Effluent after the constructed wetland

Parameter(mg/l)	Influent	Effluent	Law limits (48 for 1982)
PH value**	8	7.77	6:9
DO	3.23	5.7	Not less than 4
BOD	104	25	30
Ammonia	2.71	0.5	--
COD	196	47	50
TSS	93	36	50
TDS	2065	748	1000
T.P	2.92	2.4	3
T. N	26.46	11	15
LEAD	0.125	0.01	0.01
cadmium	0.128	0.01	0.01
chrome	0.141	0.05	0.05
sulphates	0.86	0.86	--
E. coli***	1898	733	1000

**N/A
*** CFU/100 ml

From the above achieves, the experimental results showed improvement in the water quality parameters (DO, BOD, COD, TSS, TDS, E-coli, TN&TP) with about (44%, 75%, 76%, 62%, 64%, 62%, 58% and 18%) respectively.

Then, the efficiency of enhancement of water quality parameters of El Khadrawia drain using wetland (leman plant pond) is about about 75% and the water quality parameters is within the allowable law limits for reuse practices.

Table (3-b) Effluent from constructed wetland

E	End of June	End of July	End of August	Law limits (48 for 1982)
Temp.	40	40	37	Not more than 3 degrees of the recipient water body
PH value	7.9	7.84	7.59	6:9
DO	5.6	5.7	6	Not less than 4
BOD	28	25	23	30
COD	50	48	45	50
TSS	43	45	39	50
TDS	889	749	607	1000
T. P.	1.35	1.4	1.45	3
T. N	13	11	10	15
LEAD	0.01	0.01	0.01	0.01
Cadmium	0.01	0.01	0.01	0.01
Chrome	0.05	0.05	0.05	0.05
E. coli	838	758	603	1000

*Degree
** N/A
***CFU/100 ml

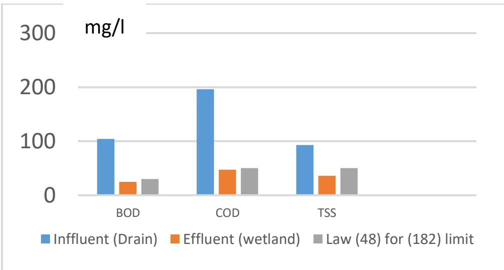

Figure (7) Influent and Effluent water quality parameters (BOD, COD, TSS)

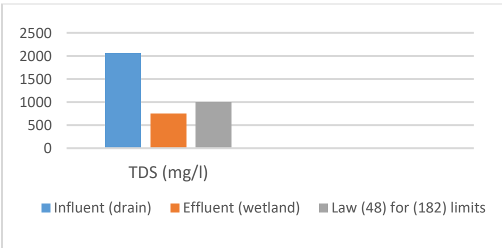

Figure (8) Influent and Effluent water quality parameters (TDS)

Subsequently, the pollutants concentration loads decrease in the effluent of the constructed wetland. Therefore, the constructed wetland pond efficiency in improvement El Khadrawia drain water quality parameters in is about 75% as shown in figure (7), and figure (8) and these parameters met with the allowable Law 48 for (1982) limits for reuse practices and the disposal for freshwater body.

5 Conclusion

The application of natural systems is a unique treatment method to enhance water quality. To improve the water quality, Bio-treatment is an innovative and sustainable method that make use of natural processes including introduction of agricultural wastes, algae application, introduction and wetland vegetation, soils, and their associated microbial assemblages to improve water quality.

An area assessment has been held for the research area to verify the requirement for improving El Khadrawia drain's water quality for reuse purposes before field sampling and laboratory analysis took place. Since El Khadrawia drain is a significant point source for El Atef drain, the assessment area is 1.5 km before and after the point of intersection between the two drains. Three field samples are collected 1.5 km before and after the intersection of El Khadrawia and El Atef drains during the summer, which is the worst time for operations. An increase in the pollutants load is indicated by the laboratory analysis of the water quality parameters (BOD, COD, TSS, TDS, E-coli, TN&TP) with about 75% for the previous water quality parameters. In comparison to the previous water quality parameters, there has been a 75% increase in the pollutants load for the values of BOD, COD, TSS, TDS, E-coli, TN&TP, according to the laboratory analysis.

After what has been illustrated, three seasonal field samples, during Spring, Summer, Autumn & Winter) are collected from El Khadrawia drain for laboratory analysis. Laboratory analysis has been recorded for the water quality parameters of El Khadrawia drain. The experimental results show that the values of (BOD, COD, TSS, TDS, E-coli, TN&TP) exceed the allowable limits for Law 48 for (1982) for reuse practices.

As a result of the assessment, the study suggested a constructed wetland using Lemna plants as a biological media to improve its water quality to be used in irrigation. The pond. area of the wetland is designed with an area of (10*7.5m) (75 m^2) with depth (40 cm). The flow is 30 m^3/day. The pond is covered with polyethylene sheets to avoid seepage. The approach recommend three field samples are taken during Summer Season at the end of June, the end of July& at the end of August. The experimental results showed improvement in the water quality parameters (DO, BOD, COD, TSS, TDS, E-coli, TN&TP) by approximately (76%, 75%, 88%, 61%, 61%, 58%, and 18%) respectively. These results revealed that the water quality parameters became within the allowable limits of law no. (48) for year (1982) and conducted that the efficiency of improvement in water quality is about 75%.

From all previous work and discussions, its well achieved that the application of lemna plant in a constructed wetland pond is an applicable treatment approach environmentally, economically and technically.

6. Conflicts of interest

"There are no conflicts to declare".

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